Establishment of frameworks for the evaluation of evidence relating to traces of drugs

Joseph Bell Centre for Forensic Statistics and Legal Reasoning,
School of Mathematics, The University of Edinburgh,
and
Mass Spec Analytical (MSA), Bristol.

EPSRC CASE studentship.

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A PhD CASE studentship is available at the Joseph Bell Centre for Forensic Statistics and Legal Reasoning in the School of Mathematics in collaboration with Mass Spec Analytical (MSA), Filton, Bristol, (http://www.msaltd.co.uk) under the supervision of Professor Colin Aitken.

Fees and stipend are available for UK national. For the purposes of the award this is someone who has settled status in the UK, meaning that they have no restrictions on how long they can stay **and** been 'ordinarily resident' in the UK for three years prior to the start of the grant. This means they must have been normally residing in the UK **and** not been residing in the UK wholly for the purpose of full-time education (though this does not apply to UK nationals). The stipend will be current EPSRC rates with a top-up from the industrial partner and is expected to be about £16,000 in the first year. There is also a travel budget to enable attendance at conferences and for research visits.

The successful candidate will be based in the School of Mathematics at the University of Edinburgh, with excellent library and computing facilities and a flourishing postgraduate community.

It is part of the condition of the award that the student spends at least three months of the project working at MSA in Bristol. It is expected this will be in three annual periods of one month each. MSA will provide the cost of travel to and from Bristol and of accommodation for this placement.

Qualifications: Applications are invited from graduates with a first-class Honours or Master's degree in a mathematics degree with a substantial statistics component or a statistics degree or from final-year undergraduate or Masters students on such a degree programme, or equivalent.

Vetting: Applicants may be subject to UK security vetting.

Start date: This is open to negotiation but the latest possible starting date is October 1st 2010.

Application: Please submit a CV, the names and addresses of two referees and a covering letter to Ms Gill Law, Graduate School Secretary, School of Mathematics, King's Buildings, The University of Edinburgh, Mayfield Road, Edinburgh, EH9 3JZ; g.law@ed.ac.uk; fax 0131 650 6553. Electronic applications are acceptable.

Further particulars

Work to be carried out in the proposed studentship project:

Novel scientific methods have been developed by MSA by which the presence, quantity and retention properties of drugs on various substrates are determined. The substrates are typically mobile phones, clothing, banknotes, and vehicles. The drugs to be analysed are typically diacetylmorphine (heroin), MDMA, cocaine, THC (cannabis) and amphetamine. Additionally, MSA determine the stable isotopic composition of drugs, plastics and other materials in order to associate or discriminate forensic exhibits.

The work has two main parts.

The first part is *data collection*. Experiments will be designed and analysed to simulate drug-related activities using the same substrates as in background data analyses and to determine transfer and persistence properties for various drugs on the substrates. Isotopic compositions will also be determined.

MSA have background databases for levels and compositions of drugs obtained from convenience samples over many years. Methods for further data collection relating to drugs from each substrate will be investigated. Data can be obtained as follows. MSA have mobile phones that have been returned to the service provider and then passed on. Clothing may be obtained from unclaimed luggage from airports. Banknotes may be obtained from banks, chosen to represent the flow of notes around the country which will need to be modelled. At present, banknotes are collected mainly from banks visited by employees in connection with their work. Data from vehicles are acquired mainly from rental and valeting companies. Data from plastics are acquired by purchasing material such as clingfilm and tape samples from local retailers. One aspect of this project will be to consider and counter criticisms in courts about the representative nature of these samples, for example by considering adjustments to the inference process. A crime database will be constructed using data associated with pleas or verdicts of guilty.

The second part concerns evidence evaluation. Evidence will be evaluated in the form of a likelihood ratio to compare the relative support for the propositions that the data recovered from the defendant's environments are, or are not, associated with the crime under investigation. The development will differ from the form currently in use as there are few control data. These will be replaced by data from crimes considered to be solved which will provide a distribution for the levels of drugs found on materials associated with crimes. Data on drugs and plastics will be in the form of compositional data concerning the isotopic composition of the items of interest. There will be additional data relating to transfer and persistence of drugs on the various substrates; for example, to determine a time interval for the transfer of the drugs to the substrate based on the level of material found on it at the current time. For plastics, the problem is to match plastics from one source with another.

A third part concerns presentation of the data in a court. This will consider the relevance of a quantification of the uncertainty associated with the likelihood ratio estimate. This aspect is potentially very important but will only be a minor part of the proposal.

Relevant papers:

1. Aitken,C.G.G. and Lucy, D. (2004) Evaluation of trace evidence in the form of multivariate data. *Applied Statistics*, **53**, 109-22, 665-666.;

2. Zadora,G., Neocleous.T. and Aitken,C.G.G. (2010) A two-level model for evidence evaluation in the presence of zeros. *Journal of Forensic Sciences* in press.;

3. Ebejer,K.A., Brereton,R.G., Carter,J.F., Ollerton,S.L. and Sleeman,R. (2005) Rapid comparison of diacetylmorphine on banknotes by tandem mass spectrometry. *Rapid communications in mass spectrometry*, **19**, 2137-43.

4. Dixon, S.J., Brereton,R.G., Carter,J.F. and Sleeman,R. (2006) Determination of cocaine contamination on banknotes using tandem mass spectrometry and pattern recognition. *Analytica Chimica Acta*, **559**, 54-63.

5. Ebejer, K.A., Winn,J., Carter,J.F., Sleeman,R., Parker,J. and Körber,F. (2007) The difference between drug money and a "lifetime's savings". *Forensic Science International*, **167**, 94-101.

Specific scientific challenges to be addressed:

There are a number of substrates on which drugs of interest may be found. In the general population the presence of drugs arises from contamination or secondary (or subsequent) transfer. Different drugs have different chemical structures and different physical properties which lead to different levels of adherence and persistence on the receptor material for each of the substrates. For example, the time for which THC from cannabis persists on banknotes is considerably shorter than that of cocaine and the quantity that persists appears considerably less. One challenge is to model transfer and persistence of drugs to substrates to determine a meaningful estimate of the time from contamination.

MSA have developed thermal desorption techniques, which are more rapid, to eliminate the use of solvents in the analysis of drugs. Different areas of the same exhibit may be examined and a better model provided for the distribution of drugs throughout the exhibit.

One statistical challenge is the development of robust models for the evaluation of evidence collected from the substrates involved in the crime, background data and the data from earlier crimes in a form which may be presented in a court of law and which takes account of quantity, location, dispersion and persistence as well as, in certain cases, isotopic composition. Care has to be taken as

there are uncertainties in the quantification of the drugs on these items arising from the efficiency of the collection and the ionisation efficiency of the analytical process and also the dispersion arising from the transport of the material from the crime scene to the laboratory. There is also an inherent variability in the effect of the material on the persistence and retention of the drugs, for example between shirts and trousers. Results from [1, 2] will be extended to allow for all these additional factors (e.g., such as autocorrelation amongst banknotes), with the aid of ideas from [3, 4, 5].

Another statistical challenge is the investigation of the feasibility of constructing a sampling frame for the collection of background data from each of the substrates. In the case of banknotes consideration will be made of the movements of cash around the country. MSA have been criticised about the representative nature of the convenience samples currently used to provide perspective to the level of drugs found in relation to the defendant. This criticism will be investigated and consideration as to how it may be countered, something relevant to a current Law Commission consultation paper, details of this aspect of which are given later.

Other factors, specific to particular substrates, to be considered are as follows.

For mobile phones there are spatial data concerning contamination as individual buttons and seams can be examined separately. The significance of the number of places, the total amount, the number and type of drugs identified and their distribution will be investigated.

For banknotes the solvent approach typically integrates a pile of notes into one response. The thermal desorption procedure developed by MSA enables the examination of individual notes with the result that the distribution of the levels of drugs amongst the notes (one, two or many notes contaminated) and the autocorrelation of these between notes may be examined and included in the statistical models.

In the case of plastics, drugs and certain other materials, results will be provided by isotope ratio mass spectrometry. Thus, it is possible to assess whether two exhibits may be determined to come from different sources. The question of interest to be answered is the strength of the inference that can be made when it is thought that the exhibits may come from the same source.

Supervision arrangements:

The academic supervisor will be Colin Aitken, Professor of Forensic Statistics at the University of Edinburgh. He has published many papers and co-authored two books with one more to appear in April 2010. He has been consulted as an expert in many criminal cases, including two involving drug contamination of banknotes.

The School of Mathematics at Edinburgh University provides an ideal envi-

ronment for graduates with excellent computing and library facilities. Research activities are grouped with those of Heriot-Watt University through the Maxwell Institute, with numerous graduate courses, seminars, conferences, workshops, a visitor programme and close links with the International Centre for Mathematical Sciences.

The industrial supervisor will be Dr. Richard Sleeman, Scientific Director of MSA. For most of his career he has specialised in the detection of trace quantities of drugs and explosives and has published over thirty scientific papers and articles on the subject. He has been involved in the development of the techniques and methodologies employed in the examination of drugs traces on paper currency. He has presented such work in Court nearly 100 times, including three at the Appeal Court.

The activities of MSA will provide a stimulating industrial research environment for the student. They have a number of patents, particularly related to drugs and explosives detection. They have collaborated with government organisations and have sold specialist equipment e.g. to Procter & Gamble and the FBI. They have configured and supplied equipment based on their systems to companies and law enforcement agencies in the UK and overseas. They also have an excellent track record in collaborating with academic institutions, including six universities in the UK and Oak Ridge National Laboratory (USA), with many resultant publications. This has included 2 PhD students and several MSc students. Several have taken up employment within MSA. MSA encourage their employees to participate fully in courses and conferences related to forensic science and MS. The student will enjoy opportunities to participate in interdisciplinary team work and build external links and collaborations.

The student will spend a month in each year of the project at MSA near Bristol. They will learn about data collection and gain first-hand experience of the different sources of variation for the data, taking into account the uncertainty budgets of the various forms of analysis. They will also explain to MSA research and development of the models for the analysis and interpretation of the data and install the software for MSA as it is developed. By interfacing with a team of forensic scientists engaged in a wide variety of disciplines in an UKAS-accredited environment, they will acquire a range of skills that will equip them ultimately to provide expert evidence in the courts.

There will be regular communication between Edinburgh and MSA. There will be much liaison, including a two-day initial meeting, concerning data analysis. The data are essentially intensity versus time for ten separate ion pair transitions, 12000 scans per transition in 20 minutes. There is a GUI to load the data into MatLab. The raw data are transformed into integrated peaks which correspond to the 'events' (*e.g.*, the injection of a standard or the analysis of a banknote). So, for each ion pair we end up with a series of integrated background subtracted peaks which it should be easy to deal with in any package. The student will need to become familiar with the criteria used to identify peaks, and how the data are processed. That will be done in Bristol. Raw data

files are typically less than 2 megabytes, and can be transferred via an ftp site.

Potential benefits and impact:

MSA are the market leader in this area of scientific research. As such, they are able to provide very considerable quantities of data which are not available from any other source. These unique data have to be modelled statistically using novel techniques. The statistical models have also to be able to be interpreted in an evidential context which is comprehensible to triers of fact in a court of law, such as judges and juries. This project aims to do this. The outcomes will be of considerable benefit to MSA and, by extension, to the administration of justice in the UK, and elsewhere.

MSA have an unrestricted drugs license and so are able to obtain samples of any drugs it wishes. It is an approved supplier of forensic services for the National Policing Improvement Agency and has worked with all 43 police forces in England and Wales, including the Metropolitan Police and British Transport Police, for many of the police forces in Scotland and for PSNI in Northern Ireland. It is of considerable benefit to the project to have access to databases of such high quality which will enable the development of statistical models of greater applicability.

A beneficial impact for society will be a reduction in the numbers of wrongful convictions and wrongful acquittals as well as a deterrent effect for those considering future crimes. A beneficial impact for the economy will be a reduction in the costs of the associated legal cases and appeals, and the accrual of confiscated assets to the Treasury.

There will various opportunities for knowledge transfer. These will include presentations at conferences such as those of the RSS and of the Forensic Science Society, the Eighth International Conference of Forensic Statistics to be held in Seattle, USA, in 2011 and the meeting of the European Academy of Forensic Sciences in The Hague 2012. Papers will be written for statistical, forensic scientific and analytical chemistry journals.

The collaborative research opportunities will also lead to knowledge transfer opportunities. For example, MSA are extremely active within the Forensic Isotope Ratio MS network organising inter-laboratory studies worldwide. Their skills in the analysis of isotopic composition led to a contract with the FIA, the international body for the regulation of F1 motor racing, to be the sole provider worldwide of a method to analyse fuels for their isotopic content. The involvement of the student in the workings of MSA will enable cross-fertilisation of ideas.

It is likely the project will increase the effectiveness of the administration of justice. This will occur with a better evaluation of evidence in drugs-related offences. For example, the Law Commission consultation paper comments that (an) 'expert would also need to show that any database relied on was sufficient

in terms of size and quality to justify the nature and breadth of inferences drawn from it, that the inferences are logically sound and that the alternative explanations were considered and properly discounted (if the data support a range of conclusions).' (para. 6.29.) The research associated with this proposal will help to satisfy this need and hence save valuable time and resources in the legal process.

The Scottish Mathematical Sciences Training Centre (SMSTC):

The SMSTC is a consortium involving the seven Scottish Universities with post-graduate mathematics programmes and provides a raft of first-level graduate courses for PhD students delivered by video-conferencing technology. New post-graduates are required to enrol in at least three of the eight courses which will be on offer. For further information see the website www.smstc.ac.uk.